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Proposal for a Technical Report on the development of global technical regulation No. xx on the measurement procedure for two- or three-wheeled motor vehicles equipped with a combustion engine with regard to test type III (crankcase emissions) and test type IV (evaporative emissions) (ECE/TRANS/WP.29/GRPE/2016/2)

Technical Report on the development of global technical regulation No. xx on the measurement procedure for two- or three-wheeled motor vehicles equipped with a combustion engine with regard to test type III (crankcase emissions) and test type IV (evaporative emissions)

A. Introduction

1. The industry producing two- and three -wheeled vehicles in the scope of this UN global technical regulation (UN gtr) is a global one, with companies selling their products in many different countries. The Contracting Parties to the 1998 Agreement have determined that work should be undertaken to address the environmental performance requirements from two- and three-wheeled vehicles of category 3 as a way to help improve air quality internationally. The aim of this UN gtr is to provide measures to strengthen the world-harmonization of vehicle approval and certification legislation, in order to improve the cost effectiveness of environmental performance testing, remove trade barriers, reduce the overall complexity of global legislation, remove potential areas of conflict or opposing requirements and improve the air quality world-wide.

2. The internal combustion engine converts chemical energy (fuel) into movement and heat, but at the same time emits toxic air pollutants and greenhouse gases as undesirable by-products. Besides exhaust gas emissions that are produced during and after combustion which escape through the vehicle’s tailpipe to the atmosphere, there are also other sources of pollution emitted possibly if not properly contained and processed; crankcase and evaporative gaseous emissions.

3. The total crankcase gas mass flow within the engine has a number of potential sources, some are significant and others contribute less to this engine internal crankcase gas mass flow:

(a) exhaust gas mass flow under high pressure containing pollutants continuously escapes from the combustion chamber via the crevasses of the piston rings and/or between piston rings and cylinder wall into the crankcase;

(b) non-evaporated fuel during cold start; after cold start when the cylinder walls are still cold fuel vapour condensates in puddles on the cold cylinder walls which partly flows into the crankcase without being combusted. In the crankcase this liquid fuel mass partly evaporates in the crankcase when the lubrication oil becomes hot, the heavier fractions of this fuel mass may remain dissolved in the lubrication oil;

(c) liquid fuel running into the crankcase via the cylinder walls may also stem from excessive enrichment of the air-fuel mixture in the combustion chamber during high engine-load operation at high combustion temperatures, which might be applied to increase power or to cool the catalytic converter;

(d) evaporation of the lighter fractions of the lubrication oil in the crankcase system at hot engine operation.

4. The higher the level of wear of the piston rings, cylinder walls and valve seals, the more this partial, non-desirable crankcase gas mass flow as well as liquid fuel mass losses into the crankcase may occur. With other words, the mass flow of crankcase gases inside the engine will increase dependent on progression in engine life. At the same time the level of crankcase gas mass flow within the engine is a function of how well the engine is designed (tolerances) and how well the crankcase control system is able to contain the crankcase gas mass flow within the engine (breather or vacuum based crankcase gas control system). In an effective crankcase emission control system this mixture of toxic and acid

crankcase gases from all these different sources will be collected within the engine, mixed with fresh air and be evacuated into the intake system of the engine in order to be combusted. It is therefore important that the crankcase gas flow system is gas-tight in order to prevent that the crankcase gases escape directly into the environment and also prevent that the rider is exposed to these harmful gaseous emissions when being positioned over the engine.

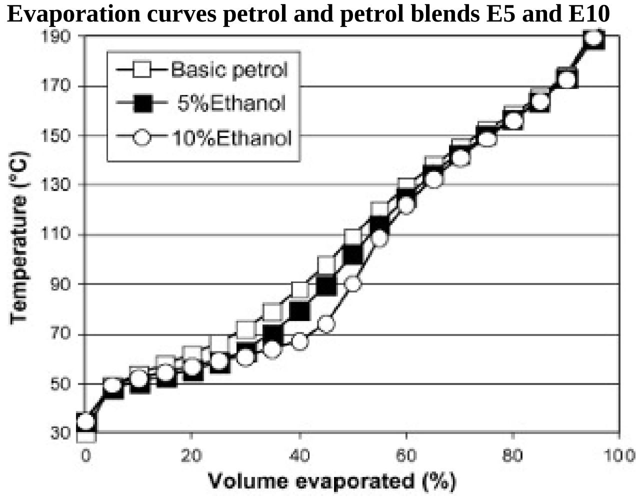
5. Evaporative emissions of mainly hydrocarbons from Positive Ignition (PI) fuel storage and supply systems are also considered to be toxic or may cause other adverse environmental effects. Breathing losses through the tank vent and fuel permeation through tank and tubing material are in general the most important sources of evaporative emissions of a vehicle.

6. Breathing losses are due to evaporation of petrol in the tank during driving, hot soak and normal daily (diurnal) temperature variation. Fuel permeation can also occur through plastic and rubber components of the fuel system.

7. The highly volatile substance in the fuel tank and fuel delivery system that evaporates is petrol. Diesel is low-volatile fuel owing to its inherent characteristics and this is the reason that the EPPR IWG decided to exclude Diesel-fuelled vehicles from the scope of the evaporative emission requirements in the UN gtr. An evaporative emission test is only required for high volatile fuels used in PI engines. The level of evaporation is depending on the ambient temperature as well as the temperature of the petrol. For example cold petrol from the fuel station entering the fuel tank and hitting the hot tank walls, for example owing to exposure to the sun and/or heat dissipation from a hot driven engine, will lead to a high level of evaporation of the petrol in the tank, given by its evaporation or boiling curve. Especially positive changes in temperature, e.g. a vehicle parked outside which cooled down during night and warming up during the day by the sun, leads to high levels of vapour within the fuel tank that has to be contained and be evacuated to the engine in order to be combusted.

Figure 2

Evaporation curves petrol and petrol blends E5 and E10



NB for basic petrol 50% of the fuel tank volume evaporates at a petrol temperature of 90 ºC.

8. In conventional passenger car powertrain designs vapour emissions are controlled by means of an activated carbon canister connected to the fuel tank to store the petrol vapour as well as to allow clean air to enter into the evaporative control system. The clean air mixes with the fuel vapour and this diluted gaseous mixture enters the air induction system of the engine and subsequently the combustion chamber. Similar evaporative emission control systems are present on e.g. motorcycles that are placed on the market in countries that already have strict evaporative emission requirements in place in their domestic legislations.

Figure 3

Typical schematic lay-out of an evaporative emission control system and the flow of fuel vapour and clean air into the engine.

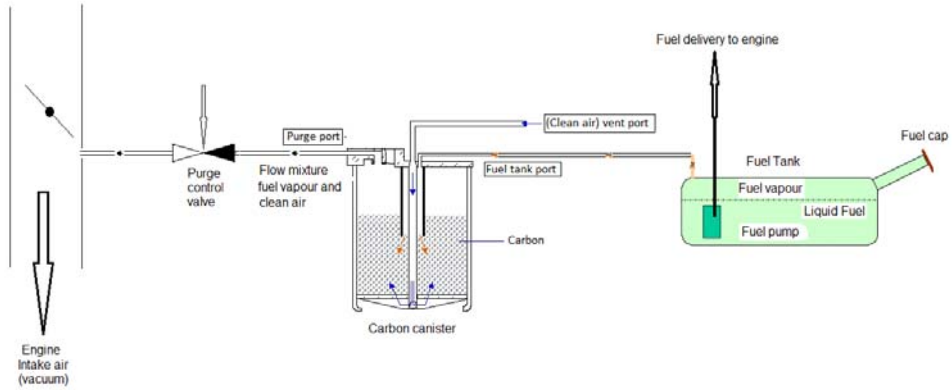
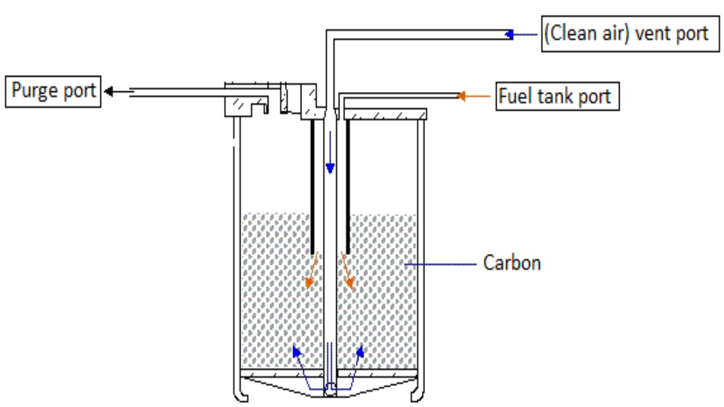


Figure 4

Flow of fuel vapour mixed with clean air through the carbon canister



9. It should be noted that in general two- and three-wheeled vehicles are equipped with a significantly smaller fuel tank compared to the ones fitted on passenger cars. The fuel tank size is an important parameter to determine how much fuel vapour can physically be generated in the fuel tank. As a rule of thumb it may be expected that the bigger the size (surface) of the fuel tank, the more vapour can be generated, which means that possibly in a passenger car fuel tank significantly more vapour can be formed than in the small fuel tank of a two- or three-wheeled vehicle. Other aspects to be taken into account are the size of the large vehicle fleet of two- and three-wheeled vehicles in some countries with hot ambient

climatic conditions, the fact that these smaller sized vehicles possibly cool down and warm up faster than passenger cars, the fuel tank is generally closer located to the hot engine and exhaust system compared to the ones from cars as well as the exposure level of the fuel tank and delivery system to solar radiation. This might offset the inherent advantage of a smaller fuel tank and the lower levels of vapour generation in the fuel tank from two- and three-wheeled vehicles. It is therefore important to quantify the evaporative emissions by conducting a world-harmonised measurement procedure and to set technology neutral performance limits to ensure that the evaporative emissions from two- and three-wheeled vehicles are properly controlled and minimised.

10. Significant scientific work has been conducted with respect to evaporative emissions of passenger cars. For a more complete description of issues and aspects with respect to evaporative emissions please refer to the documents[1] which has been made available to the EPPR IWG experts for their review and analysis. Although the conclusion and recommendations apply to passenger cars these are deemed to be also relevant for two-and three-wheeled vehicles in the scope of this UN gtr.

11. Two pollutants, fine particulate matter and ground-level ozone, are generally recognised as the most significant in terms of human health impacts. Long-term and peak exposures can lead to a variety of health effects, ranging from minor effects on the respiratory system to premature mortality. Explained in a simplified way, Volatile Organic Compounds (VOC) are hydrocarbon molecules clogged together as volatile particles at room temperature. The concentration of VOC in the ambient air is an important precursor for the level of smog in the atmosphere.

12. In addition the mass of evaporated hydrocarbons from the fuel tank and delivery system is not any longer available for combustion as the mass of hydrocarbons is directly expelled into the atmosphere and does therefore not contribute to any movement of the vehicle. Evaporated fuel losses therefore represent waste which is paid for by the consumer but which does not bring added value. These are all important reasons to continue reducing hydrocarbon pollutants emitted from road vehicles among others, reducing not only tailpipe emissions but also evaporative emissions and avoiding any emission of crankcase gases.

13. The European Commission launched an EPPR study for L-category vehicles in January 2012 with the objective to develop proposals to update UN gtr No. 2 for technical progress and to develop proposals for GTRs and UN Regulations with respect to harmonised EPPR legislation not yet covered at the international level for vehicles in the scope of this UN gtr, e.g. crankcase and evaporative emission test requirements, on-board diagnostic requirements, propulsion unit performance requirements etc. The output of this comprehensive study[2] was submitted for the review and comments of the EPPR IWG with the objective to identify the concerns and to provide base proposals ready for further enhancements by the EPPR IWG in order to accommodate the needs at the international level to assess a vehicle with respect to its crankcase and evaporative emissions in a scientifically based, objective and globally accepted way.

14. The outcome of this work was the development of a first draft UN gtr proposal among others based on the consolidation of existing global legislation and up-to-date

[1] Presentation DG JRC: EPPR-10-03e and associated documentation EPPR-10-19e
Report 1 JRC: http://iet.jrc.ec.europa.eu/sites/about-jec/files/documents/EVAP_eur22713en_Final2007.pdf
Report 2 JRC: http://publications.jrc.ec.europa.eu/repository/bitstream/JRC77061/final_evap_report_online_version.pdf

[2] EPPR-07- 07

technical provisions. After discussions and adopting a number of amendments the EPPR group decided to take the EC proposal as a basis for the first draft UN gtr of the group. This text then further evolved in many different revisions and was modified in iterative steps by the group in order to reflect the discussions and decisions by the group over the period 2013 - 2015.

15. This UN gtr covers the following test types:

(a) Test type III, emissions of crankcase gases;

The section on emissions from crankcase gases includes the obligation for the vehicle manufacturer to issue and submit a statement at approval to ensure that no emissions from the crankcase gas ventilation system can escape to the atmosphere during the useful life of the vehicle. In a future amendment of this UN gtr the section on test type III will be expanded with one or more physical, harmonised test procedures which the approval authority may request under to be defined conditions. The test procedure will be designed to validate the statement issued by the vehicle manufacturer that no crankcase emissions are escaping to the atmosphere during the useful life of the vehicle.

(b) Test type IV, evaporative emissions.

The section on evaporative emissions includes a cascade of three tests to determine the evaporative emissions, from either a simple fuel tank permeability test for a non-metallic fuel tank, from a permeation test of the fuel tank and fuel delivery system, or from a SHED based test to determine the evaporative emissions from the whole vehicle in a sealed house test.

B. Objective of the UN gtr on test types III (crankcase emissions) and IV (evaporative emissions)

16. The objective of this UN gtr is to prevent crankcase emissions from being emitted without being combusted and to reduce the evaporative emission contributions from vehicles in the scope of this UN gtr during their useful life. Harmonised test procedures are set out allowing to measure the crankcase and evaporative emissions and subsequently to allow comparison of the measurement results with world-wide harmonised test thresholds for the approval of a vehicle.

17. The harmonised test procedures to determine the crankcase emissions and evaporative emissions of vehicles in the scope of this UN gtr are part of the environmental performance tests approval and assessment of such vehicles. The test procedures were developed so that they would be:

(a) Able to provide an internationally harmonised set of tests to ensure efficient, cost-effective and practicable testing;

(b) Corresponding to state-of-the-art testing, affordable but sampling and measurement technology fit for purpose in the area of performance testing of vehicles; and

(c) At a later stage, when the appropriate requirements have been agreed upon and are incorporated in this UN gtr, applicable in practice to existing and foreseeable future powertrain technologies. However, the first priority has been to address crankcase and evaporative emissions from (currently) conventional vehicle configurations and propulsion unit types.

C. Controversially discussed subjects in the area of test types III (crankcase emissions) and test type IV (evaporative emissions), compromises and decisions taken by the EPPR IWG

18. A number of subjects within the draft UN gtr on test types III and IV led to discussions within the EPPR IWG and the different views and positions among the participants were debated, sometimes leading to long-standing open issues. For the largest share of these more difficult subjects a compromise could be worked out; for a few subjects the EPPR IWG decided to postpone the discussions and to reopen the debate at a later point in time when more scientific evidence is collected and available for assessment. The controversially discussed subjects, the associated compromises and decisions by the EPPR IWG are the following:

19. For both test types III (crankcase emissions) and IV (evaporative emissions):

(a) Scope;

The scope is a horizontal issue for all the draft UN gtrs developed by the EPPR IWG. It concerned many differences in view, among others raising the questions:

(i) if three-wheeled and even certain light four-wheeled vehicles should be taken in the scope of the draft UN gtr?;

(ii) if other propulsion unit types then only the conventional combustion engine should be included and if yes at which point in time?;

(iii) if the classification criteria of Special Resolution No 1 are still appropriate and whether the specific classification symbols 3-1, 3.-2, 3-3 etc. should be directly referenced or the reference should be done in a more generic way?;

(iv) if the exclusion criteria of the scope should be set out in table B1.-1 or if these exclusion criteria should have been described in full text?;

(v) how to deal with a mono-fuel gaseous fuelled vehicle equipped with a PI combustion engine?;

The scope has been one of the most challenging items to be resolved but the EPPR IWG managed to find a solution for all the different questions and concerns expressed by the participants and finally settled for a compromise as set out in the draft UN gtr.

(b) Reference fuel;

Another horizontal issue for all EPPR GTRs in development has been the reference fuel specifications. The relevant questions were among others:

(i) which types of reference fuels should be prescribed, all regional fuel types or just a reduced set?;

(ii) if the reference fuel has to be blended with ethanol or not?;

(iii) if the reference fuel specifications could be centrally stored in a repository like e.g. in a revised UN gtr No2 or as for example an annex of a mutual resolution?;

The EPPR IWG decided that for the moment it is appropriate to specify the E0 reference fuel (95 Research Octane Number (RON)), set out in the current UN gtr No. 2, in the dedicated Annex of the UN gtr and to supplement this specification with 2 additional E0 reference fuels (90, resp. 100 RON), with E5 (95 RON) and with 3 types of E10 reference fuel (90, 95 and 100 RON). It has to be noted that all 7 reference fuels have the same Reid Vapour Pressure (60 kPa) and some representatives in the EPPR IWG therefore questioned if it would really be necessary to specify so many different types of reference fuels. It was decided to collect scientific data and to assess what the impact of the different fuel characteristic parameters may be, besides the Reid Vapour pressure and the Ethanol blend contents on the results of the evaporative emission test . When sufficient scientific data is available and deemed acceptable the EPPR IWG will undertake efforts to reduce the number of reference fuels and amend the UN gtr accordingly in due course.

(c) Definition and provision on "useful life";

The need for a definition of "useful life" has been debated at length in the EPPR IWG and based on coherence with UN gtr Nos. 4, 5 and 11 the EPPR IWG has decided to include a definition as well as a provision in the draft UN gtr in order to clarify during which time frame or accumulated distance and under which conditions the evaporative emission requirements have to be complied with by the vehicles represented by the tested parent vehicle used to approve the vehicle type.

20. For test type III in particular:

The need for the inclusion of physical crankcase emission test requirements and associated test procedures;

For the cases that the approval authority has doubts on the statement of the vehicle manufacturer or if the engine is equipped with a different and new type of crank case emission control system the initial EC proposal contained 2 alternative physical tests to verify if the crankcase emission control system is leak tight preventing any crankcase emission to escape to the atmosphere without being combusted. However, the tests were not accepted by the EPPR IWG initially and therefore it was decided to start harmonising requirements by requesting a written statement from the vehicle manufacturer that the crankcase is designed appropriately and sealed such that no crankcase gases can escape from being combusted. The EPPR IWG postponed the discussions on the physical test procedure as well as on the conditions under which the physical test may be requested by the approval authority and targets to address these issues in a future amendment.

21. For test type IV in particular:

(a) Adaptation of provisions to two- and for three-wheeled vehicles where necessary;

In general the EPPR IWG concluded that the test procedures designed for two-wheeled vehicles could also be applied for certain categories of three-wheeled vehicles, without further adaptations of these test procedures and test performance limits. The EPPR IWG subsequently agreed upon taking three-wheeled vehicles in the scope of the draft UN gtr under the condition of adding reference to Special Resolution No. 1 (S.R.1) in a footnote and by adding an explanation in a paragraph added to part A of the proposal.

(b) Test types and test hierarchy

Providing a series of options three alternative evaporative emission test types to allow testing to be carried out involving varying degree of complexity and measurement equipment of higher technical complexity and cost (i.e. from a simple mass based permeability test for a plastic fuel tank requiring simple and cheap test equipment to a full vehicle test requiring expensive and complex SHED test equipment);

The proposed simple permeability test of a non-metallic fuel tank as most relevant component with respect to evaporative emissions and the slightly more complex permeation test which allows measuring the evaporative emissions from the fuel tank and fuel delivery system were not deemed equivalent to the full assessment of the evaporative emissions of the entire vehicle by means of a SHED test. The EPPR IWG assumed that in general the evaporative emissions of a two-wheeled motorcycle, a motorcycle with a side car and tricycle should be tested in accordance with the SHED test procedure. However, the IWG agreed to give some flexibility to Contracting Parties in dealing with two-and three-wheeled Mopeds by applying one out of the three test procedures set out in the UN gtr. Subsequently a hierarchy of the three test procedures was proposed, discussed and accepted by the EPPR IWG.

(c) The appropriate SHED test preparation and preconditioning test cycle;

For two-wheeled vehicles in the scope of UN gtr No 2 the EPPR IWG agreed to assume the WMTC providing appropriate preparation and preconditioning test conditions. For three-wheeled vehicles in the scope of the draft UN gtr it was less obvious to identify a harmonised emission laboratory test to ensure sufficient heat accumulation as well as providing ample time to purge the carbon canister as preconditioning for both the diurnal and hot soak test before switching off the engine. It was therefore proposed to allow the national type I test cycle for three-wheeled vehicles under 2 conditions.

The first condition was to ensure that the engine is warmed up and running at stable operation temperature conditions achieved by condition 2. Condition 2 requires a minimum total test-time of 780s, which has been derived from the length of the test cycle in accordance with UN Regulation No 40. This timeframe should also be sufficient for preconditioning of the evaporative control system of vehicles subject to the UN Regulation No 47 test cycle, if applicable in the national legislation. For any other test cycle defined for such three-wheeled vehicles in the scope of the UN gtr it should be ensured that stable warm-up conditions have been achieved and have stabilised, ensured by the supplemental requirement that the vehicle shall be driven for at least 780s after start under the transient conditions given by the type I test cycle. In case the prescribed Type I test time is less than 780s, the running shall be continued until at least 780s is reached. In order to reduce burden of testing and owing to the fact that a side-car does not add evaporative emissions to the test results of the assembly of two-wheeled motorcycle and sidecar, it is appropriate that the motorcycle with sidecar is exempted from the type IV emission test under the condition that the base two-wheeled motorcycle has passed the SHED test.

(d) Durability of evaporative emission control devices.

There were many and long discussions in the EPPR IWG on subjects related to durability of evaporative emission control devices, among others:

(i) Confirmation on applying a fixed deterioration factor as alternative to physical durability testing of evaporative emission control devices;

In order to reduce burden of testing applying a fixed deterioration factor on the evaporative emission test results in the permeation and SHED test were adopted by the EPPR IWG. The debate focussed on the representativeness of using a degreened vehicle and evaporative emission control devices and to account for reduced efficiency of the evaporative control system by subtracting a fixed deterioration factor from the final test result. Pros and cons have been assessed and finally the group decided to allow this mathematical method as alternative to physically ageing the evaporative emission control components such as ageing the carbon canister by repeatedly charging and discharging the canister with petrol vapour as test fuel.

(ii) The notion of "degreened" evaporative emission control device;

In the context of test types III (crankcase emissions) and IV (evaporative emissions), in particular with respect to the evaporative emission control device such as the carbon canister, the notion "green" means not used and having its maximum absorption efficiency. When a green canister coming straight from the production line is charged and discharged with fuel vapour a couple of times the absorption efficiency reduces and stabilizes at a fairly constant level, given that the carbon canister is correctly operated by the engine management system and the canister is not poisoned with liquid fuel after break-through. This reduced but stabilised-at-a-constant-level-of-absorption is referred to as a "degreened" carbon canister and deemed representative for day-to-day vehicle use during its useful life. The EPPR IWG decided that the vehicle manufacturer may apply a proprietary developed "degreening" method of the carbon canister before fitting it on the parent vehicle to be tested in the SHED test under the condition that this methodology is properly described and made available to and accepted by the approval authority.

(iii) Incorporation of bench ageing durability test procedure B (based on California evaporative emission requirements);

Owing to the fact that the SHED test procedure is based on the current evaporative emission test procedure for motorcycles in California it seemed obvious to also include the associated bench ageing durability test procedure in the UN gtr. However, the initial UN gtr proposal only included the canister ageing methodology applied in the EU. Subsequently after the debate and assessing pros and cons the EPPR IWG decided to allow inclusion of both physical bench ageing tests of the canister, of which one may be opted for by the Contracting Parties as deemed appropriate.

(iv) The number of charging and discharging durability cycles for ageing procedure A;

Ageing test procedure A of the carbon canister is the methodology as applied in the EU. Initially 300 subsequent charging and discharging cycles on a bench with petrol vapour had been proposed for high performance two-wheeled motorcycles, similar as applicable in the approval requirements in the EU. However, the EPPR IWG also accepted the number of charging and discharging cycles set out in the EU for low and medium performance motorcycles and therefore accepted to expand the table with these motorcycle displacement categories and prescribed amount of charging and discharging durability cycles of the carbon canister. After this bench durability test of the canister it is to be fitted on the parent vehicle before start of the SHED test to approve the vehicle type.

(v) Blending of the reference fuel with ethanol affecting the durability of the carbon canister;

The effect of ethanol on evaporative emissions has been discussed in the EPPR IWG and was explained among others through the documentation referred to in the introduction of this report (point 10). The EPPR IWG acknowledged the scientific justification and need to age the carbon canister with test petrol vapour blended with ethanol as well as to conduct the applicable evaporative emission test with such representative test fuel for some countries. However, in large parts of the world E5 or E10 petrol is not available in the markets and therefore for the time being the EPPR IWG decided to specify all reference fuels needed by Contracting Parties, but at the same time a limiting the amount of test fuels to be used which are specified in a dedicated section of the draft UN gtr. Upon availability of scientific statistical data and a larger availability of ethanol blended market fuel on the domestic markets around the globe the EPPR IWG may reconsider this subject in the future. For the sake of harmonisation and reduction of test burden the EPPR IWG may then consider reducing the number of specified test fuels. Another alternative that was discussed in the EPPR IWG was applying a hierarchy of test fuels, similar as applied for the 3 test types, but this was not adopted as long as scientific evidence is missing.

(vi) Durability requirements of evaporative emission control valves and linkages;

The initial provision set out in the evaporative emission legislation for motorcycles in California was proposed as provision, but the EPPR IWG required more clarity on the test procedure and especially on the proposed "5000" cycles. As no harmonised test procedure was readily available to age valves, linkages and cables the EPPR IWG decided to delete the initially proposed provision from part B of the proposal and to make note in part A of the draft UN gtr that in the future this provision might be reinserted through an amendment upon availability of harmonised and agreed test procedures for these types of devices.

(e) Criteria of the propulsion unit family;

Several parameters from the propulsion unit family have been discussed at length, especially the parameter with respect to the acceptable fuel tank size tolerance. It was argued that the worst case condition should be tested for this parameter, meaning that no positive tolerance is allowed. Counter arguments in the debate were that the family boundaries have not been developed as worst-case conditions but as an acceptable tolerance band with which the parent test vehicle should comply. Meeting the requirements with the parent vehicle does not relief the vehicle manufacturer from the obligation that all vehicle categories which are represented by the parent vehicle shall comply with the evaporative test requirements and test performance limits. The EPPR IWG worked out a compromise by allowing a +10% tolerance on the nominal tank volume under the condition that the approval authority may request another vehicle to be tested, including such a vehicle that is equipped with a +10% tank volume on top of the nominal tank volume.